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(71) Applicant (for all designated States except US): STMICROELECTRONICS ASIA PACIFIC PTE LTD [SG/SG]; 28 Ang Mo Kio Industrial Park 2, Singapore 569508 (SG).

(72) Inventors; and

(75) Inventors/Applicants (for US only): GOH, Kwong, Huang [SG/SG]; Block 323 Jurong East Street 31,

(74) Agent: DONALDSON & BURKINSHAW; P.O. Box 3667, Singapore 905667 (SG).

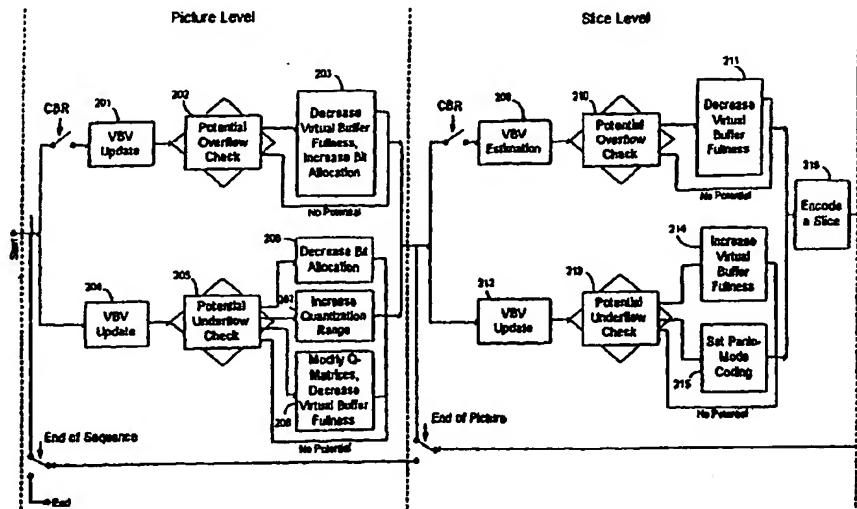
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(54) Title: METHOD AND APPARATUS FOR VIDEO BUFFER VERIFIER UNDERFLOW AND OVERFLOW CONTROL



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(57) Abstract: A method and apparatus for Video Buffer Verifier (VBV) underflow and overflow control. A combination of picture and slice level control is used in the method and apparatus. Improved prevention of overflow and panic mode encoding is achieved by means of adjustment of the virtual buffer-fullness which allows the quantization-step to have an improved response to the buffer-fullness at both high and low critical levels. The use of a non-linear quantization scheme and customised quantization matrices also provide improved prevention of panic mode encoding. The slice level control also reduces the computation complexity compared to the macroblock level control.

# Method And Apparatus For Video Buffer Verifier Underflow And Overflow Control

5

## Technical Field

10 The present invention relates to Video Buffer Verifier (VBV) control of a video encoder, and in particular, to the efficient prevention of VBV underflow and overflow during MPEG-2 video encoding.

## Background Art

15

### VBV constraints in MPEG-2

The MPEG-2 coded bitstreams are required to meet the constraints imposed by the Video Buffer Verifier (VBV). The VBV is provided with an input buffer known as the VBV buffer which is conceptually used to simulate the entering and removing of coded data to and from a decoder's buffer.

20  
25 Typically, constraints are imposed which require the entering and removing of the coded data so that the VBV buffer does not overflow or underflow. These constraints are used to guarantee that the decoder buffer will not overflow or underflow.

30 A virtual VBV buffer is maintained in the encoder and its buffer-fullness is updated to emulate the buffer-fullness in the decoder (refer to figure 1). Buffer overflow arises when a picture consumes too few bits while the decoder is nearly full. The bits which arrive at the decoder during the next picture period

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will then cause an overflow. Note that this overflow constraint applies only to the constant bit-rate application. Buffer underflow occurs when a picture generates too many bits. The constraints of underflow and overflow are considered separately.

5

VBV buffer-fullness,  $VBV\_fullness_t$ , where  $t$  is the picture period, is updated after encoding one picture as follows:

$$VBV\_fullness_t = VBV\_fullness_t - S \quad (1)$$

10

where  $S$  is the number of bits used for the encoded picture.

At this point, the MPEG-2 underflow constraint states that after the above buffer-fullness update, the buffer-fullness shall not be less than zero:

15

$$VBV\_fullness_t \geq 0 \quad (2)$$

The VBV buffer is then filled with the average number of bits per picture,  $Bpp$ , which is *Bit\_rate* divided by *frame\_rate* (for variable bit-rate operation, the 20 maximum bit-rate is used to calculate  $Bpp$ ):

$$VBV\_fullness_{t+1} = VBV\_fullness_t + Bpp \quad (3)$$

and at this point, the overflow constraint specifies that for a constant bit-rate 25 operation the VBV buffer shall not be greater than the VBV buffer size:

$$VBV\_fullness_{t+1} \leq VBV\_buffer\_size \quad (4)$$

Details of the VBV specifications can be found in Annex C of the 30 Recommendation ITU-T H.262 (ISO 13818-2 MPEG-2) the disclosures of which are herein incorporated by reference.

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MPEG2 TM-5 rate control

In the MPEG-2 Test Model-5 (TM-5) of an MPEG-2 video encoder, "virtual buffer-fullness", is used to determine the reference quantization parameter.

5 Before encoding macroblock  $j$  ( $j \geq 1$ ), the fullness of the appropriate virtual buffer is computed:

$$d_j^i = d_0^i + B_j - 1 - T_i(j-1) / MB\_cnt$$

or

$$10 \quad d_j^p = d_0^p + B_j - 1 - T_p(j-1) / MB\_cnt$$

or

$$d_j^b = d_0^b + B_j - 1 - T_b(j-1) / MB\_cnt$$

depending on the picture type,

15

where,

$d_0^i$ ,  $d_0^p$ ,  $d_0^b$  are initial fullness of virtual buffers - one for each picture type;  
 $B_j$  is the number of bits generated by encoding all macroblocks in the picture, up to and including  $j$ ;

20  $MB\_cnt$  is the number of macroblocks in the picture; and  
 $d_j^i$ ,  $d_j^p$ ,  $d_j^b$  are the fullness of virtual buffers at macroblock  $j$  - one for each picture type.

25 The final fullness of the virtual buffer ( $d_j^i$ ,  $d_j^p$ ,  $d_j^b$ :  $j=MB\_cnt$ ) is used as  $d_0^i$ ,  $d_0^p$ ,  $d_0^b$  for encoding the next picture of the same type.

The reference quantization parameter  $Q_j$  for macroblock  $j$  is then computed as follows:

$$30 \quad Q_j = (d_j * 31) / r$$

where the "reaction parameter"  $r$  is given by

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$$r = 2 * \text{bit\_rate} / \text{picture\_rate}$$

and  $d_j$  is the fullness of the appropriate virtual buffer.

5 The initial value for the virtual buffer-fullness is:

$$\begin{aligned} d_0^i &= 10 * r/31 \\ d_0^p &= K_p d_0^i \\ d_0^b &= K_b d_0^i \end{aligned}$$

10

where  $K_p$  and  $K_b$  are "universal" constants dependent on the quantization matrices.

#### VBV control

15

It is to be noted that the following prior art relating to VBV buffer overflow and underflow control algorithm descriptions are typically performed prior to encoding a picture, and after the VBV buffer-fullness rises by  $Bpp$ .

20 Underflow control

In typical VBV underflow control, such as that disclosed in US Patent No. 5,650,860, two levels of control are performed. First, the picture level, and then, the macroblock level.

25

To control buffer underflow in picture level, the target bit  $T$  for the next picture is adjusted when necessary such that it does not lead to underflow:

$$VBV\_fullness - T >= 0 \quad (5)$$

30

In addition to the picture-level preventing of buffer underflow, macroblock (MB) level control is utilised by means of defining a level above the

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“VBV\_fullness=0” level named the “panic level”. If the VBV\_fullness should fall below this level, then the encoder will enter “panic mode”. In this mode, only the minimum amount of data to maintain the integrity of the bitstream will be transmitted. In the panic mode all DCT coefficients and all motion vectors 5 are set to zero, thereby generating a minimal amount of conforming encoded data.

To detect this panic level, macroblock (MB) level updating of VBV buffer-fullness is therefore required. The VBV\_fullness is updated after encoding each 10 MB:

$$VBV\_fullness = VBV\_fullness - S_{mb} \quad (6a)$$

if (  $VBV\_fullness < panic-level$  ) -----> Enter Panic mode coding (6b)

15 where  $S_{mb}$  is the number of bits used to encode the macroblock. The encoder will enter the panic mode coding when VBV buffer-fullness is less than panic level.

20 Overflow control

As disclosed in US Patent No. 5,650,860, to avoid VBV overflow, adding zero “stuffing bits” to the bitstream is utilised, when VBV overflow occurs after 25 encoding a picture. However, instead of simply stuffing bits to the bitstream which is considered a waste, the encoder may first determine, prior to encoding a picture, if there are “extra bits”, and add a value *extra\_bits* to the target bits, *T*, to increase the bits used for the current picture that is to be encoded, which is given by:

$$30 \quad extra\_bits = VBV\_fullness - T + Bpp - VBV\_buffer\_size \quad (7)$$

$$If (extra\_bits > 0) then \quad T = T + extra\_bits \quad (8)$$

After encoding the current picture, only the necessary number of filling bits are added to the bitstream.

- 5 It has been found that the picture-level overflow control is unable to prevent VBV buffer overflow effectively when a sequence switched from a high level of motion (having lots of scene-changes) to a low level of motion. One of the reasons is that the assumption used in equation (7) is not true most of the time.
- 10 Equation (7) assumes that the bits used for coding the current picture is equal to the target bits allocated  $T$  to forecast the amount of *extra\_bits* required. This assumption is generally not true which is why the prediction of overflow at picture level is quite poor.
- 15 Another reason is that the quantization-step which is quite high during a "fast" sequence does not "react" or reduce fast enough when there is a sudden change to a "slow" sequence, therefore generating insufficient bits and causing the VBV buffer to overflow.
- 20 If a sequence of pictures are to difficult to encode at a given bit-rate (for example due to a very noisy and action-packed sequence or a synthetic sequence with lots of scene-changes coded at a low bit-rate), when even the maximum quantization-step is used and still could not be sustained at the given low bit-rate, the VBV buffer will reach the panic level.
- 25 The prior art prevention method of adjusting the target bits allocation  $T$  at picture level is not able to control bits in the VBV buffer when encoding a difficult sequence at a low bit-rate. Using the target bits allocated  $T$  to judge the potential of underflow is also not effective.

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In panic mode encoding all DCT coefficients are set to zero, the intra-coded macroblocks will appear as "grey-level" blocks subsequently followed by B and P pictures which could be quite irritating, subjectively, to a user.

5 This identifies a need for a new type of Video Buffer Verifier (VBV) control of a video encoder which overcomes the problems inherent in the prior art.

### Disclosure Of Invention

10 In a preferred embodiment, the present invention seeks to provide improved prevention of panic mode encoding, improved underflow and overflow prevention, and improved quality of video. This is sought to be achieved by implementing additional picture and slice level controls which include:

- 1) Virtual buffer fullness control ( $d_0$ );
- 15 2) Quantization-step range control (linear/non-linear quantization); and/or
- 3) Optional quantization matrices modification.

As macroblock level control is generally required in the panic mode detection and this control has higher implementation costs, it is also sought to be provided 20 by the present invention that the complexity of VBV control is reduced by using slice level control instead of MB level control.

The present invention further seeks to provide a method for Video Buffer Verifier (VBV) control of a video encoder, whereby picture and/or slice level controls 25 are implemented in the method, said picture and/or slice level controls including:

virtual buffer fullness control for increasing the sensitivity of a Q-step;  
and/or  
quantization-step range control for increasing the range of the Q-step.

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The present invention also seeks to provide a method wherein, the method additionally includes quantization matrices modification for the prevention of panic mode coding.

5 Preferably, slice level control is used in place of an MB level control.

In a broad form, the present invention provides that the method results in improved prevention of an underflow or an overflow.

10 In a further broad form, the present invention provides that the method results in improved encoding at a low bit-rate.

Preferably, the video encoding is MPEG-2 video encoding.

15 The present invention according to one aspect seeks to provide a method which includes the following steps:

at the picture level control:

updating the VBV buffer-fullness in at least one VBV Update module before at least one Potential Overflow Check module;

20 reducing the virtual buffer-fullness and increasing the target bit allocation in a Decrease Virtual Buffer-Fullness and Increase Bit Allocation module;

if there is an underflow potential, then according to that underflow potential level: reducing a target bit  $T$  in a Decrease Bit Allocation module; increasing quantization range in an Increase Quantization Range module; and/or 25 modifying the quantization matrices and reducing the virtual buffer-fullness in a Modify Q-Matrices and Decrease Virtual Buffer-Fullness module;

at the slice level control:

estimating the VBV buffer-fullness in a VBV Estimation module;

30 checking for an overflow potential in a Potential Overflow Check module; if an overflow potential is found, decreasing the virtual buffer-fullness in a Decrease Virtual Buffer-Fullness module;

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for underflow control, updating the slice level VBV in a VBV Update module;

performing a potential underflow check in a Potential Underflow Check module;

5 after determination of the underflow potential level: increasing the virtual buffer-fullness in an Increase Virtual Buffer-Fullness module; and/or setting the panic mode coding in a Set Panic Mode Coding module; and  
encoding a slice in an Encode a Slice module.

10 In a further broad form of the present invention, the present invention also seeks to provide that the method assists in panic mode coding prevention by addition of a preventive margin to a target bits factor  $T$ .

15 In another preferred form of the invention it is sought to provide that a variable panic level may be used.

The present invention according to another aspect seeks to provide a method wherein, for constant bit-rate coding:

at the picture level:

20 overflow prediction is rendered more sensitive by incorporating a factor dependent on the encoding bit-rate; and

reducing the virtual buffer-fullness when a factor *extra-bits* is greater than 0;

at the slice level:

25 estimating the VBV buffer-fullness in each slice and reducing the virtual buffer-fullness if required.

Also preferably, - specified levels of buffer-fullness are experimentally determined for each picture type.

30 In a specific embodiment of the present invention, values of  $Th1$ ,  $Th2$  and  $Th3$  are 200 000, 150 000 and 100 000 respectively for a PAL picture.

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In a further embodiment of the present invention there is provided an apparatus for Video Buffer Verifier (VBV) control of a video encoder, whereby the apparatus contains integrated picture and/or slice level controls, said picture and/or slice level controls including:

5 a virtual buffer-fullness control for increasing the sensitivity of a Q-step;  
and/or  
a quantization-step range control for increasing the range of the Q-step.

10 Broadly, the apparatus additionally includes quantization matrices modification for the prevention of panic mode coding.

In accordance with a specific embodiment of the present invention there is provided apparatus which at the picture level includes:

15 at least one VBV Update module;  
at least one Potential Overflow Check module;  
a Decrease Virtual Buffer Fullness and Increase Bit Allocation module;  
a Decrease Bit Allocation module;  
an Increase Quantization Range module; and  
20 a Modify Q-Matrices and Decrease Virtual Buffer-Fullness module;

and at the slice level said apparatus includes:  
a VBV Estimation module;  
a VBV Update module;  
a Potential Overflow Check module;  
25 a Potential Underflow Check module;  
a Decrease Virtual Buffer-Fullness module;  
an Increase Virtual Buffer-Fullness module;  
a Set Panic Mode Coding module; and  
an Encode a Slice module.

30

In another preferred form of the invention there is provided a method for Video Buffer Verifier (VBV) control of a video encoder, substantially according to the

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method described in the specification with reference to the accompanying figures.

In another preferred form of the invention there is provided an apparatus for  
5 Video Buffer Verifier (VBV) control of a video encoder, substantially according  
to the embodiment described in the specification with reference to and as  
illustrated in the accompanying figures.

### **Brief Description Of Figures**

10 The present invention will become apparent from the following description, which is given by way of example only, of a preferred but non-limiting embodiment thereof, described in connection with the accompanying figures, wherein:

15

- Figure 1 illustrates a preferred embodiment of the present invention wherein, the figure shows an illustration of how a VBV buffer is updated.
- Figure 2 illustrates a preferred embodiment of the present invention wherein, the figure shows a block diagram illustrating picture and slice level VBV control.
- Figure 3 illustrates a preferred embodiment of the present invention wherein, the figure shows a detailed flow diagram the picture and slice 20 level VBV buffer underflow and overflow control.

25

### **Modes For Carrying Out The Invention**

30 In a particular embodiment, the present invention is directed to the prevention of VBV underflow and overflow during MPEG-2 video encoding.

Underflow control

## Picture level:

5

The basic step in underflow and panic mode coding prevention is the reducing of the target bits  $T$  when necessary. The target bits  $T$  in equation (5) are replaced by  $(T+PM)$  where  $PM$  is defined as the preventive margin to take care of the additional bits that might be used to encode the next picture.

10

Apart from adjusting the target bits  $T$ , additional picture level prevention steps can be used.

15

A further preventive step is to increase the range of the quantization-step (Q-step) to be used, for example the MPEG-2 non-linear quantization scheme allows the quantization-step to go up to 112. This is used when a potential of panic mode occurrence is detected.

20

A still further preventive step which may be optionally employed is to use customised quantization matrices which are of higher values than the default Q matrix, when a higher potential of panic mode encoding is detected.

## Slice level:

25

Instead of using the MB level of updating and checking panic level encoding, slice level is used to reduce computation requirements and the potential of panic mode coding of individual MB.

30

Slice level underflow control for panic mode detection and prevention is performed after encoding each slice of a picture. A Variable Panic Level (VPL) may be used. The VPL varies according to the number of remaining slices ( $j$ ) to be coded. The slice panic level is made variable depending on the remaining

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number of slices yet to be encoded to further optimise the VBV control such that the encoder does not go into the panic mode prematurely.

In addition, a slice level adjustment of the virtual buffer-fullness,  $d_0$ , (described 5 hereinbefore and in the rate-control of MPEG-2 TM-5) is performed when necessary. When there is a potential of panic mode encoding, the value of  $d_0$  (one for each picture-type) is increased to ensure that the quantization-step (which is computed based on the value of  $d_0$ ) can reach the maximum value in a shorter time interval.

10

Overflow Control (for constant bitrate coding only)

Picture level:

15 As hereinbefore discussed, the picture level overflow prediction described in equations (7) and (8) is not effective. To render the prediction more sensitive, the value of  $T$  in equation (8) is replaced by a value  $P$  which depends on the encoding bit-rate of the encoder.

20 In addition, the virtual buffer fullness  $d_0$  is reduced when *extra\_bits* in equation (8) is greater than 0, in an attempt to reduce the Q-step more rapidly during the encoding of next picture.

Slice level:

25

The VBV buffer-fullness is estimated in each slice to check if the VBV buffer is going to be filled up, and  $d_0$  is further reduced if necessary.

More Detailed Description

30

A preferred, but non-limiting, embodiment of the present invention is shown in figure 2. This figure shows the block diagram of the apparatus in accordance

with the picture and slice level VBV control of the present invention. Note that overflow control is generally only carried out for constant bit-rate encoding.

At the picture level control, the VBV buffer-fullness is updated in the VBV

5      Update modules 201 and 204 before the potential overflow and underflow check  
modules 202 and 205 respectively.

The virtual buffer-fullness  $d_0$  is reduced and the target bit allocation is increased  
in module 203 if there is an overflow potential. If there is an underflow  
10     potential, according to the underflow potential level, one or more actions  
including reducing target bit  $T$  (module 206); increasing quantization range  
(module 207); and modifying the quantization matrices and reducing the virtual  
buffer fullness (module 208) are carried out.

15     At slice level (a row of MB), the VBV buffer-fullness is estimated in module  
209. If an overflow potential is found in module 210, virtual buffer-fullness  $d_0$   
is decreased in module 211. For underflow control, the slice level VBV update  
is performed in module 212 and the potential underflow check is performed in  
module 213.

20     Depending on the underflow potential level, actions are taken in module 214 to  
increase the virtual buffer fullness  $d_0$  and in module 215 to set the panic mode  
coding.

25     Figure 3 shows an example of the detailed flow diagram of the picture and slice  
level underflow and overflow control. The rate control in module 217 is a rate  
control which uses the virtual buffer-fullness  $d_j$  for determination of  
quantization-step, such as in the MPEG-2 TM-5.

30     Picture level control:

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For picture level overflow control, before encoding each picture, possible *extra\_bits* is computed in module 320 and checked in module 321 as to whether the target bits  $T$  need to be increased in module 322:

$$extra\_bits = VBV\_fullness - P + Bpp - VBV\_buffer\_size \quad (9)$$

The value of  $P$  is set depending on the encoding bit-rate, for example,  $1/4 \times B_{pp}$ .

If the target bits are required to be increased by *extra\_bits*, which indicates that the VBV buffer is about to overflow, the value of  $d_0$  is reduced by a value  $d2$  in module 324 if it is found to be greater than  $dhigh/2$  in module 323. This is to allow the Q-step to reduce fast enough when an overflow is likely in a situation such as sudden changes in motion activities from very fast to very slow.

15 In picture level underflow control, the target bits  $T$  is first adjusted if necessary in module 326:

$$\text{if } (T + PM) > \text{VBV fullness} \text{ then } T = \text{VBV fullness} - PM \quad (10)$$

20 Setting a small  $PM$  value might not be enough to take care of the bits-used discrepancy, and setting a high  $PM$  might cause “over-reaction” or unnecessary adjustment in target bit  $T$ . The value of  $PM$  used is typically experimentally determined, for example a value equal to  $Bpp$  is often found to be suitable.

25 If a sequence of pictures are to difficult to encode at a given bit-rate, when even the maximum quantization-step ( $Q_{max}=62$  for MPEG-2 linear quantization scheme) is used and still could not be sustained at the given low bit-rate, the VBV buffer will reach the panic level.

30 To prevent this from happening, the non-linear quantization (NLQ) scheme which allows the Q value to reach a higher maximum value (Qmax non linear=112 in MPEG-2) is used (module 328). The decision of

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when to use NLQ (module 327) can be made by means of checking if the VBV buffer-fullness reaches a specified low level,  $Th1$ :

5           *if (VBV\_fullness < Th1) -----> use non-linear quantization scheme*  
              *else -----> use linear quantization scheme*

Or, by means of checking whether the average Q-step of the picture has reached its maximum:

10           *if (Qmean >= Qmax\_linear) -----> use non-linear quantization scheme*  
              *else -----> use linear quantization scheme*

If using this NLQ is still not enough to cause the buffer-fullness to drop further, the optional customised inter and intra quantization matrix (which have larger values than the default Q-matrix) are then used in an effort to prevent the buffer fullness level from entering the panic level. The decision of when to use the customised Q-matrix (CQM) in module 329 can be made by means of checking if the buffer-fullness reaches an even lower level at  $Th2$ :

20           *if (VBV\_fullness < Th2) -----> use customised inter & intra Q-matrices*  
              *else -----> use default Q-matrices*

Or, by means of checking whether the average non-linear Q-step of the picture has reach its maximum:

25           *if (Qmean == Qmax\_non\_linear) -----> use customised inter & intra Q-matrices*  
              *else -----> use default Q-matrices*

30           When switching from the default Q-matrix to the customised Q-matrix (module 333), the value of  $d_0$  is reduced in module 334 by a value  $d2$  to allow the Q-steps to have some room for adjustment.

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In a preferred embodiment of the present invention, the values of  $Th1$ ,  $Th2$  and  $Th3$  are experimentally determined as 200 000, 150 000 and 100 000 respectively for PAL picture. The optional customised Q-matrices are scaled 5 versions of the default Q-matrices. The scaling factor used is 1.25 for Intra-Q-matrix and 1.5 for Inter-Q-matrix. It should be appreciated that these values may be varied if desired.

Slice level control:

10

To ensure that no overflow bits are wastefully stuffed, slice level VBV buffer-fullness estimation is performed. Before encoding the current picture, the estimated\_VBV\_fullness is first initialised in module 319. After encoding each slice, the estimated\_VBV\_fullness is updated in module 303:

15

$$\text{estimated\_VBV\_fullness} = \text{estimated\_VBV\_fullness} - S_{slice} + B_{ps} \quad (11a)$$

where  $S_{slice}$  is the number of bits used to encode the slice and  $B_{ps}$  is the average number of bits per slice ( $B_{pp} / \text{number\_of\_slice\_per\_picture}$ ). The value  $d_0$  is 20 further reduced in module 305 at slice level if it is found in module 304 that the estimated\_VBV\_fullness exceeds the buffer size, VBV\_buffer\_size, so as to further increase the bits used in encoding the next slice.

$$\text{if } (\text{estimated\_VBV\_fullness} > \text{VBV\_buffer\_size}) \quad d_0 = d_0 - d1 \quad (11b)$$

25

For underflow control, the estimated VBV buffer-fullness is updated in module 306:

$$\text{VBV\_fullness} = \text{VBV\_fullness} - S_{slice} \quad (12)$$

30

where  $S_{slice}$  is the number of bits used to encode the current slice. Note that  $S_{slice}$  includes the bits used for encoding the picture header for the first slice. If the

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VBV buffer-fullness is found in module 307 to be lower than threshold  $Th3$ , the value of  $d_0$  is increased in module 309 by a value  $d2$  to ensure that the quantization-step can reach the maximum value quicker, if it is found in module 308 that it has not reach its upper limit  $dhigh$ .

5

A variable panic level (VPL) which is defined as:

$$VPL = j * \text{Slice\_max\_panic} + \text{Slice\_max\_nonpanic} \quad (13)$$

10 is computed in module 310. The VPL varies according to the number of remaining slices,  $j$ , to be coded. The *Slice\_max\_panic* is the maximum number of bits required to encode a slice in the panic mode and the *Slice\_max\_nonpanic* is the maximum number of bits required to encode a slice in the non-panic mode but at the maximum quantization-step.

15

The slice panic level is made variable depending on the remaining number of slices yet to be encoded to make the VBV control more optimal such that the encoder does not go into the panic mode prematurely. A panic mode encoding flag is set in module 312 as an indication to the encoder, if it is found in module 20 311 that the *VBV\_fullness* goes below the VPL.

The values of  $d1$ ,  $d2$  and  $dhigh$  are experimentally determined and suitable values are 50 000, 100 000 and 500 000 respectively.

25 The values of *Slice\_max\_nonpanic* and *Slice\_max\_panic* are chosen carefully to guarantee that no underflow will occur. The values are experimentally determined and may vary according to the picture type and picture size. An example value for *Slice\_max\_nonpanic* is 10 000, and example values for *Slice\_max\_panic* are 2000 for I-picture and 150 for P and B pictures.

30

After the picture is encoded, *bits\_stuff* is computed in module 314 and checked in module 315, if there are bits-stuffing module 316 is required. Rate control

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and bit-allocation is then performed in module 317 and the VBV buffer-fullness is then updated in module 318.

The preferred embodiment of the present invention performs well in terms of 5 picture quality and buffer-fullness control. The additional picture and slice level overflow and underflow control provide improvements over the prior art, especially in terms of panic mode prevention and overflow prevention. Panic mode encoding has been avoided even for very difficult sequence coding at very 10 low bit-rate. Slice level underflow control is used in place of MB level control and the complexity requirements are reduced as well as individual MB panic mode coding avoided.

15 VBV buffer overflow is also avoided when encoding video sequences which switch from a high level of motion (having lots of scene-changes) to a low level of motion, which demonstrates that the quantization-step is able to respond quickly enough to the changes.

20 Thus, there has been provided in accordance with the present invention, a Video Buffer Verifier (VBV) control of a video encoder which satisfies the advantages set forth above.

The invention may also be said broadly to consist in the parts, elements and 25 features referred to or indicated in the specification of the application, individually or collectively, in any or all combinations of two or more of said parts, elements or features, and where specific integers are mentioned herein which have known equivalents in the art to which the invention relates, such known equivalents are deemed to be incorporated herein as if individually set forth.

30 Although the preferred embodiment has been described in detail, it should be understood that various changes, substitutions, and alterations can be made

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herein by one of ordinary skill in the art without departing from the scope of the present invention as hereinbefore described and as hereinafter claimed.

The claims defining the invention are as follows:

1. A method for Video Buffer Verifier (VBV) control of a video encoder, whereby picture and/or slice level controls are implemented in the method, said picture and/or slice level controls including:
  - 5 virtual buffer fullness control for increasing the sensitivity of a Q-step; and/or quantization-step range control for increasing the range of the Q-step.
- 10 2. A method as claimed in claim 1 wherein, the method additionally includes quantization matrices modification for the prevention of panic mode coding.
- 15 3. A method as claimed in either claim 1 or claim 2 wherein, the slice level control is used in place of an MB level control.
- 20 4. A method as claimed in any one of the claims 1 to 3 wherein, the method results in improved prevention of an underflow or an overflow.
5. A method as claimed in any one of the claims 1 to 4 wherein, the method results in improved encoding at a low bit-rate.
- 25 6. A method as claimed in any one of the claims 1 to 5 wherein, the video encoding is MPEG-2 video encoding.
7. A method as claimed in any one of the claims 1 to 6 wherein, said method includes the following steps:
  - at the picture level control:
    - updating the VBV buffer-fullness in at least one VBV Update module before at least one Potential Overflow Check module;
    - 30 reducing the virtual buffer-fullness and increasing the target bit allocation in a Decrease Virtual Buffer-Fullness and Increase Bit Allocation module;

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if there is an underflow potential, then according to that underflow potential level: reducing a target bit  $T$  in a Decrease Bit Allocation module; increasing quantization range in an Increase Quantization Range module; and/or modifying the quantization matrices and reducing the virtual buffer-fullness in a

5    5. Modify Q-Matrices and Decrease Virtual Buffer-Fullness module;

at the slice level control:

estimating the VBV buffer-fullness in a VBV Estimation module;

10    checking for an overflow potential in a Potential Overflow Check module;

if an overflow potential is found, decreasing the virtual buffer-fullness in a Decrease Virtual Buffer-Fullness module;

for underflow control, updating the slice level VBV in a VBV Update module;

15    performing a potential underflow check in a Potential Underflow Check module;

after determination of the underflow potential level: increasing the virtual buffer-fullness in an Increase Virtual Buffer-Fullness module; and/or setting the panic mode coding in a Set Panic Mode Coding module; and

encoding a slice in an Encode a Slice module.

20

8.    A method as claimed in any one of the claims 1 to 7 wherein, the method assists in panic mode coding prevention by addition of a preventive margin to a target bits factor  $T$ .

25

9.    A method as claimed in any one of the claims 1 to 8 wherein, a variable panic level may be used.

10.   A method as claimed in any one of the claims 1 to 9 wherein, for constant bit-rate coding:

30   at the picture level:

overflow prediction is rendered more sensitive by incorporating a factor dependent on the encoding bit-rate; and

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reducing the virtual buffer-fullness when a factor *extra-bits* is greater than 0;

at the slice level:

estimating the VBV buffer-fullness in each slice and reducing the virtual buffer-fullness if required.

11. A method as claimed in any one of the claims 1 to 10 wherein, specified levels of buffer-fullness are experimentally determined for each picture type.

10 12. A method as claimed in claim 11 wherein, values of *Th1*, *Th2* and *Th3* are 200 000, 150 000 and 100 000 respectively for a PAL picture.

13. Apparatus for Video Buffer Verifier (VBV) control of a video encoder, whereby the apparatus contains integrated picture and/or slice level controls, 15 said picture and/or slice level controls including:

a virtual buffer-fullness control for increasing the sensitivity of a Q-step; and/or

a quantization-step range control for increasing the range of the Q-step.

20 14. Apparatus as claimed in claim 13 wherein, the apparatus additionally includes quantization matrices modification for the prevention of panic mode coding.

15. Apparatus as claimed in either claim 13 or claim 14 wherein, at the 25 picture level said apparatus includes:

at least one VBV Update module;

at least one Potential Overflow Check module;

a Decrease Virtual Buffer Fullness and Increase Bit Allocation module;

a Decrease Bit Allocation module;

30 an Increase Quantization Range module; and

a Modify Q-Matrices and Decrease Virtual Buffer-Fullness module;

and at the slice level said apparatus includes:

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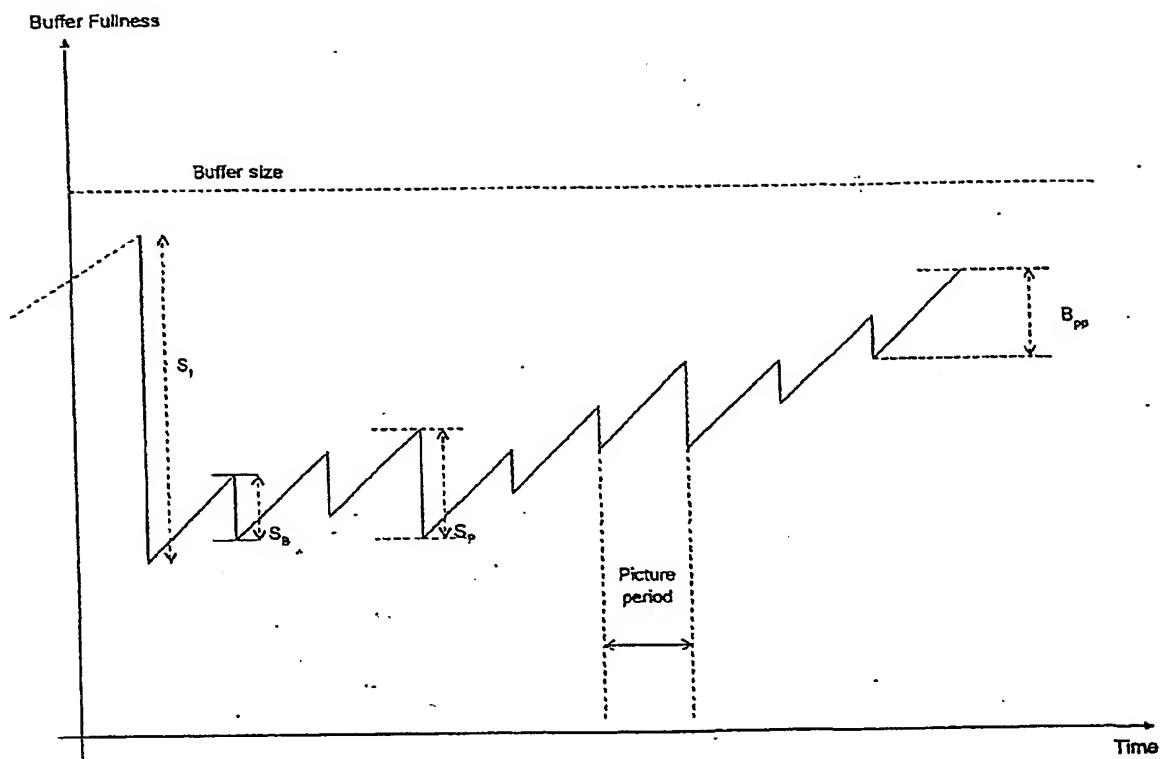
- a VBV Estimation module;
- a VBV Update module;
- a Potential Overflow Check module;
- a Potential Underflow Check module;
- 5 a Decrease Virtual Buffer-Fullness module;
- an Increase Virtual Buffer-Fullness module;
- a Set Panic Mode Coding module; and
- an Encode a Slice module.

10 16. A method for Video Buffer Verifier (VBV) control of a video encoder, substantially according to the method described in the specification with reference to the accompanying figures.

15 17. An apparatus for Video Buffer Verifier (VBV) control of a video encoder, substantially according to the embodiment described in the specification with reference to and as illustrated in the accompanying figures.

1/3

Figure 1



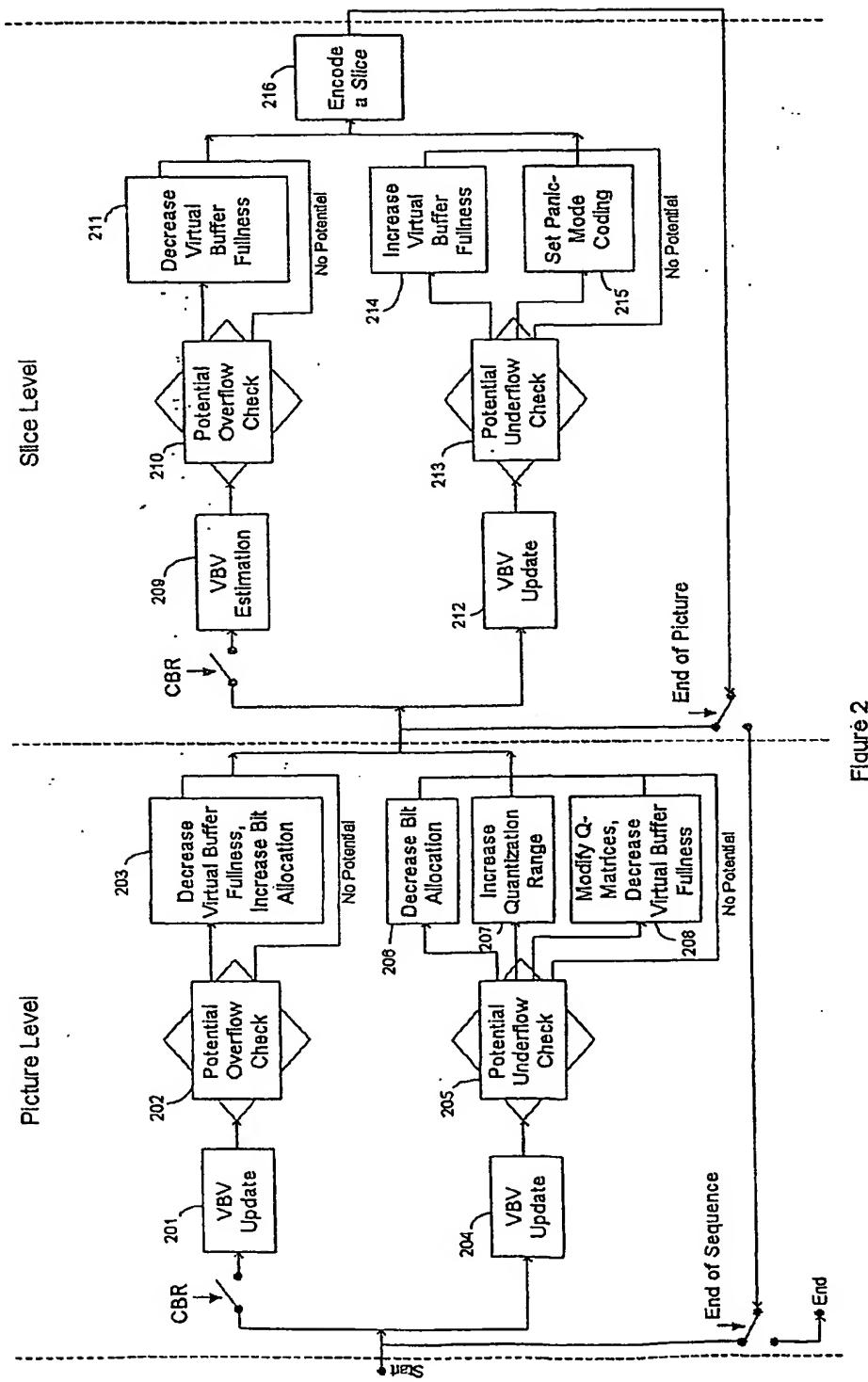
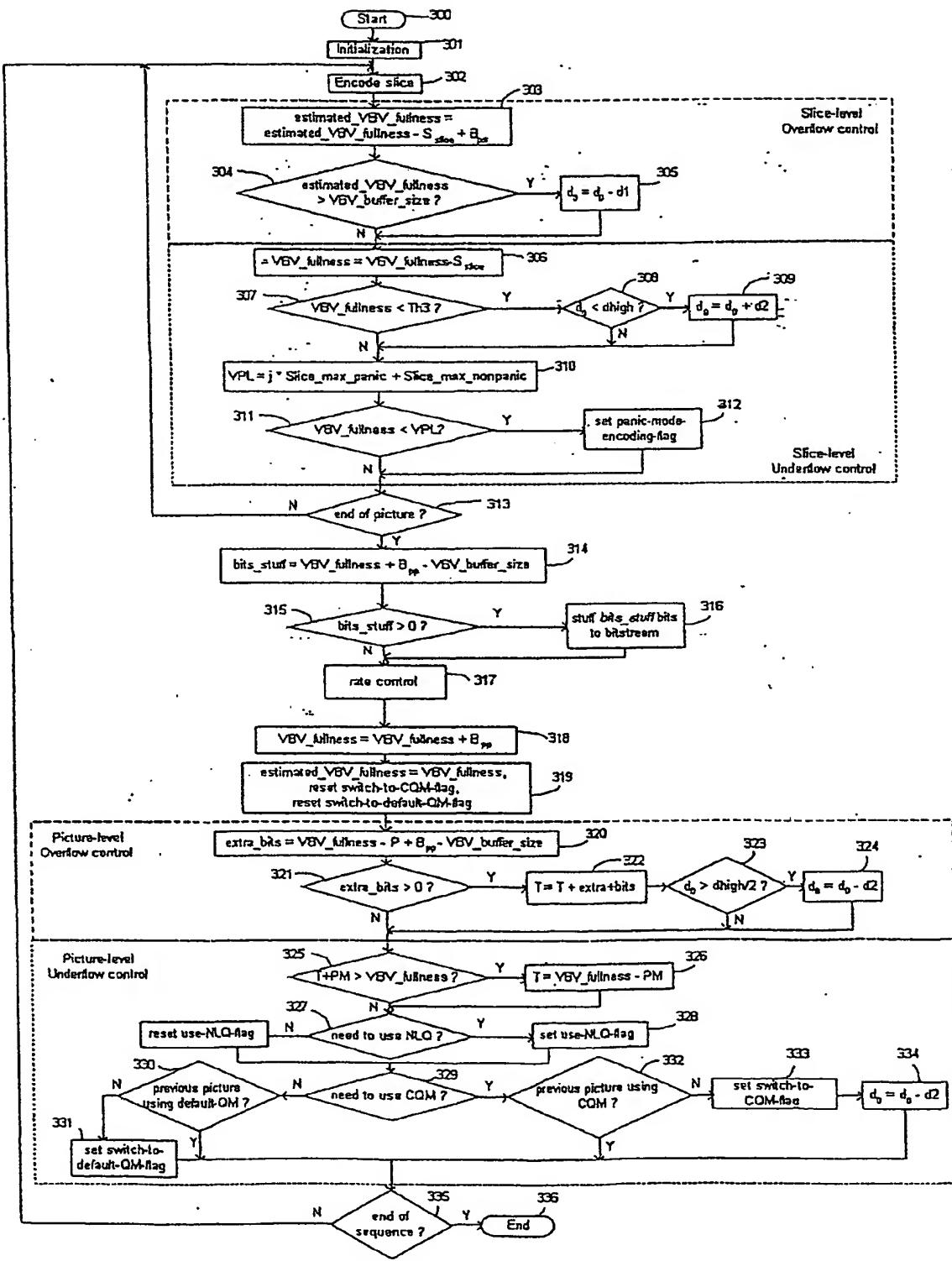


Figure 2

Figure 3



## INTERNATIONAL SEARCH REPORT

Int'l Application No  
PCT/SG 01/00019A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 H04N7/50

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Marie-Julie, J-M

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No  
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